Comparative Food Studies of Yellowfin Tuna, *Thunnus albacares*, and Blackfin Tuna, *Thunnus atlanticus* (Pisces: Scombridae) from the Southeastern and Gulf Coasts of the United States

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ABSTRACT.— Two hundred and six yellowfin tuna, *Thunnus albacares*, and 98 blackfin tuna, *T. atlanticus*, were sampled from sport fisheries in the South Atlantic and Gulf of Mexico, April 1980 to July 1982. Stomach contents were analyzed by frequency of occurrence, number of food items, and volume. Invertebrates (85%) and fish (77%) occurred in the diet of yellowfin relatively equally. Major invertebrates by frequency of occurrence were cephalopods (62%) and crustaceans (52%). Fishes were represented primarily by the families Scombridae (12.2%), Balistidae (11.2%), and Syngnathidae (8.2%). Yellowfin also ingested floating materials such as plastic, feathers, seagrasses, and balls of tar. Invertebrates occurred in 82% of the blackfin stomachs with food, and represented 75% and 31% of the foods by number and volume, respectively. Fish were found in 67% of the stomachs and constituted 26% and 68% of the food number and volume, respectively. The most frequently occurring invertebrates were crustaceans (67.4%) and cephalopods (36.0%). Fishes were represented primarily by the families Balistidae (10.1%), Trichiuridae (5.6%), and Carangidae (4.5%). Blackfin also consumed floating materials, such as plastic and seagrasses. Statistical comparisons of the diets of the two species indicated no significant correlation. Overall, their diets appear to reflect those of fast, aggressive predators, and also of fish that use their gill apparatus to strain small, near-surface items from the water.

INTRODUCTION

The family Scombridae includes many species of pelagic fish that are very important to the world's fisheries. Some, such as the mackerels *Scomberomorus* spp. and *Scomber* spp., are primarily coastal, migrating north in spring and summer and south in fall and winter. Others, including members of the genus *Thunnus*, are usually much larger than the mackerels and are reputed for their more complex, often transoceanic migrations.

Two species of *Thunnus*, the yellowfin tuna, *T. albacares*, and the blackfin tuna, *T. atlanticus*, are highly esteemed food and sport fishes whose distributions include the southeastern and Gulf coasts of the United States. The yellowfin is the largest and more prized of the two, attaining a weight of at least 176 kg (compared with 19 kg for blackfin).

On the whole, tuna landings in the western Atlantic are sporadic and are much smaller than those made by the large-scale, international hook and line and seine tuna fisheries that operate in the eastern Atlantic and Pacific. The total United States commercial landings of all tunas was 341,149,000 pounds in 1981, 326,860,000 pounds from the Pacific and 14,289,000 from the Atlantic. Only 131,000 pounds were landed in the South Atlantic Region — North Carolina, South Carolina, Georgia, and the east coast of Florida (D. S. Fitzsgibbon, pers. comm.). Of the South Atlantic total, only 5,000 pounds were identified as yellowfin tuna, and none as blackfin, although the 55,000 pounds of unclassified tunas undoubtedly included blackfin. Recreational catches of yellowfin and blackfin tunas tend to be greater than the commercial catches for the southeastern United States. In North Carolina, for instance, anglers fishing from charter boats in 1978 caught approximately 151,000 pounds of yellowfin tuna and 38,000 pounds of blackfin tuna (Manooch et al., 1981). No information is available for 1981.

Considering the disproportionately large commercial catch of tunas in the Pacific, it is not surprising that many publications pertaining to life histories, population dynamics and exploitation have resulted from research on species in that region. Relatively few studies have been conducted on Atlantic stocks. Dragovich (1969) in his review of food studies on Atlantic tunas mentioned that the papers he read emphasized the need for additional research on the foods and feeding habits of Atlantic stocks. The limited information available from the western Atlantic usually resulted from fish collected aboard scientific vessels that did not operate along the southeastern or Gulf coasts of the United States, or that operated well offshore of the normal sport fishing grounds (Dragovich 1969, 1970).

To obtain more data pertinent to the management of pelagic stocks, studies were initiated on oceanic species important to fisheries along the southeastern and Gulf coasts of the United States. Our study is the result of a cooperative effort that included the Oceanic Pelagic Program, SEFC, Miami Laboratory, and the Bioprofiles Task, SEFC, Panama City Laboratory. The objectives were to 1) identify the food habits of yellowfin and blackfin tunas; 2) compare the diets of the species collected from the same geographic area during the same period of time; and 3) determine if changes in the diets occur for different sizes of fish.

METHODS

Of the 206 yellowfin and 98 blackfin stomachs examined, 169 and 55, respectively, were from fish landed at Oregon Inlet or Hatteras, North Carolina during the spring, summer and fall of 1980, 1981 and 1982. A few additional samples, indicated in parentheses as yellowfin and then blackfin, were obtained from locations along the southeast Atlantic and Gulf of Mexico coasts: South Carolina (31,8), Georgia (3,1), east coast of Florida (0,2), northwest Florida (3,1), Mississippi-Louisiana (0,6), and south Texas (0,25).

Samplers at all locations apportioned their efforts to coincide with local charter boat activities, primarily April through October. Port samplers met boats at the docks as a day's catch was being unloaded. Most fishermen either wanted to save their fish whole for mounting, or to have them filleted and packed on ice or frozen upon returning to the dock. Data were obtained only from the latter group, either in exchange for cleaning the fish, or from fish cleaners who worked at local markets. Fish were measured to the nearest millimeter (FL) and weighed to the nearest tenth of a kilogram. Stomachs and gonads were placed in labeled cloth bags or cheese cloth and preserved in 10% formalin.

In the laboratory, stomach contents were identified to the lowest possible taxon and were enumerated, thus providing the relative number of each food type in the stomachs. Frequency of occurrence of materials was determined by counting every stomach that contained at least one specimen or part of a specific item (taxon). Empty stomachs were excluded. The volume of each taxon was obtained by water displacement and was later converted to weight by a linear regression equation. Larval and juvenile fish in the stomachs were identified after they had been cleared and stained following the methods discussed by Dingerkus and Uhler (1977) and Taylor and Van Dyke (1978). Crustaceans were identified by Steven G. Morgan and Joseph W. Goy, Duke University Marine Laboratory, Beaufort, North Carolina. Parasites, encountered only occasionally, were separated from food items, counted, identified and preserved. A stomach containing only parasites was considered empty.

All data were analyzed as percent frequency of occurrence, percent of total number, and percent of food volume. Once frequencies, volumes and numbers of the various foods were obtained, an index of relative importance (IRI) was used to estimate the contribution of major food groups to the diet (Pinkas et al., 1971). The index was calculated as: IRI = (N + V) F, where N = numerical percentage of a food, V = its volumetric percentage, and F = its percentage frequency of occurrence.

The Spearman rank correlation (r_S) was used to evaluate differences in diets of the two species based on IRI values of foods from fish collected in the same geographic area and over approximately the same period of time. Two different equations may be used. One, where there are no ties (rankings are equal for two or more food categories), and the other where ties do occur. The equation for tied food categories (Fritz 1974) was used:

$$r_s = \frac{\Sigma x^2 + \Sigma y^2 - \Sigma d^2}{2\ \Sigma x^2\ \Sigma y^2} \quad \text{where } \Sigma x^2 = \frac{N^3 - N}{N} - \Sigma Tx;\ \Sigma y^2 = \frac{N^3 - N}{N} - \Sigma Ty;$$

$T = \frac{t^3 - t}{N}$; N = numbers of ranks; d = difference between ranks; T = correlation factor for ties and t = number of observations tied at a given rank. Pearson and Kendall's Tau B Correlation Coefficients, in addition to the Spearman rank, were also derived to evaluate differences in the diets.

RESULTS AND DISCUSSION

Composition of Stomach Contents

Stomach contents of both species could be grouped into four principal categories: fish, cephalopods, crustaceans and miscellaneous nonfood items (Tables 1, 2; Fig. 1). Major representatives of each group will be discussed below under separate headings and will also be analyzed later to identify differences in diets related to the species of predator and its size. A graphic presentation of the overall contribution of selected foods to the diet (IRI plots) is presented in Figure 2.

Fish.— Fishes occurred in 77% of yellowfin and 67% of blackfin stomachs that contained food (Tables 1, 2; Fig. 2) and consisted primarily of older larvae and juveniles often associated with floating *Sargassum*. In all, 23 families were identified. Adult exocoetids, scombrids and syngnathids were found occasionally in yellowfin, as were syngnathids, serranids, sciaenids and stromateids in blackfin. For all life stages, fish that occurred most frequently in yellowfin tuna were Scombridae (12.2%), Balistidae (11.2%), Syngnathidae (8.2%), Diodontidae (5.1%) and Exocoetidae (4.6%). Fifty-three percent of stomachs with food contained unidentifiable fish remains. Fish that occurred most often in blackfin tuna stomachs were Balistidae (10.1%), Trichiuridae (5.6%), Carangidae (4.5%) and Syngnathidae (4.5%). Unidentifiable fishes were found in 44.9% of the stomachs containing food.

Cephalopods.— Cephalopods constituted almost all the molluscan food of both species. One exception was unidentifiable mollusk tissue, possibly cephalopod, from a yellowfin captured in the Gulf of Mexico. Two groups were represented: Teuthidida and Octopodida. Teuthoids (squids) were the most important by frequency of occurrence and by volume: 50.5% and 41.0% for yellowfin, 31.5% and 21.5% for blackfin. By comparison, octopodids, represented by the paper nautilus, *Argonauta argo*, appeared in only 7.7% of the yellowfin tuna and 3.4% of the

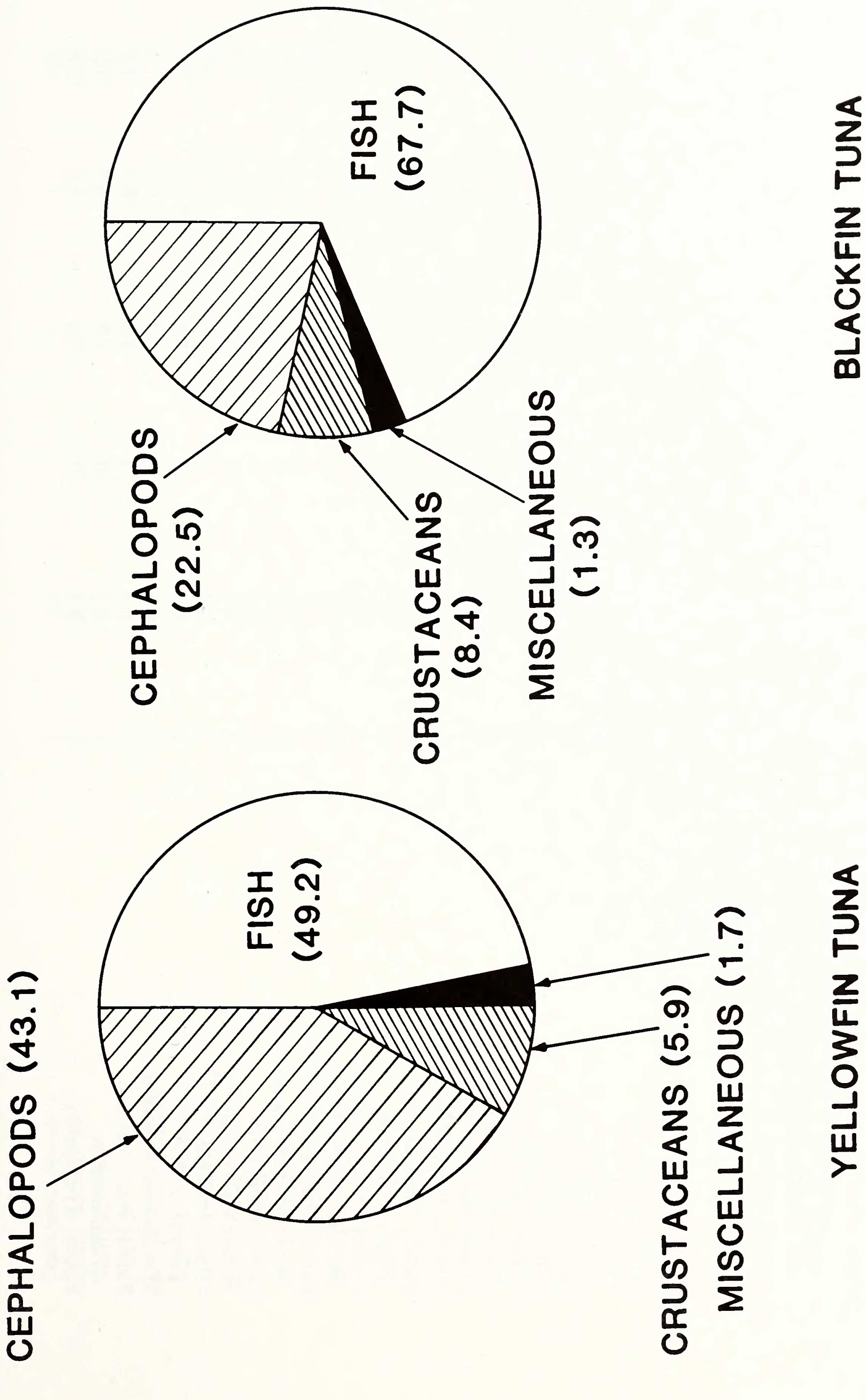

Fig. 1. Major groups of contents found in stomachs of 196 yellowfin tuna and 89 blackfin tuna, expressed as percent volume.

Table 1. Stomach contents of 196 yellowfin tuna collected off the southeastern United States and Gulf of Mexico coasts in 1980, 1981 and 1982. F = frequency of occurrence (N=196); %F = percent frequency; N = number of items (N=5,841); %N = percent by number; V = volume (N=13,316.8 ml); %V = percent of volume.

Item	F	%F	N	%N	V	%V
Fish	150	76.5	727	12.4	6,546.2	49.2
Unidentifiable	103	52.5	301	5.1	1,386.9	10.4
Unidentifiable juvenile	11	5.6	73	1.2	81.8	0.6
Family Clupeidae	1	0.5	10	0.2	745.0	5.6
Unidentifiable	1	0.5	10	0.2	745.0	5.6
Family Exocoetidae	9	4.6	18	0.3	625.0	4.7
Unidentifiable	2	1.0	2	TR	51.0	0.4
Unidentifiable juvenile flyingfish	1	0.5	1	TR	1.0	TR
Unidentifiable adult flyingfish	6	3.1	15	0.3	573.0	4.3
Family Holocentridae	1	0.5	1	TR	1.0	TR
Unidentifiable squirrelfish	1	0.5	1	TR	1.0	TR
Family Syngnathidae	16	8.2	125	2.1	177.2	1.3
Hippocampus sp.	16	8.2	125	2.1	177.2	1.3
Family Priacanthidae	2	1.0	2	TR	10.6	0.1
Pristigenys alta	2	1.0	2	TR	10.6	0.1
Family Echenidae	2	1.0	2	TR	1.1	TR
Phtheirichthys lineatus	1	0.5	1	TR	0.6	TR
Remora remora	1	0.5	1	TR	0.5	TR
Family Carangidae	8	4.1	17	0.3	72.4	0.5
Unidentifiable	6	3.1	8	0.1	56.4	0.4
Caranx crysos	1	0.5	1	TR	6.0	TR
Decapterus punctatus	1	0.5	8	0.1	10.0	0.1
Family Acanthuridae	1	0.5	1	TR	0.5	TR
Acanthurus sp.	1	0.5	1	TR	0.5	TR
Family Trichiuridae	1	0.5	1	TR	2.5	TR

Trichiurus lepturus	1	0.5	1	TR	2.5	TR
Family Scombridae	24	12.2	54	0.9	2,363.0	17.7
Unidentifiable	22	11.2	50	0.9	2,173.0	16.3
Auxis sp.	2	1.0	4	0.1	190.0	1.4
Family Stromateidae	2	1.0	33	0.6	845.0	6.3
Peprilus triacanthus	2	1.0	33	0.6	845.0	6.3
Family Dactylopteridae	1	0.5	1	TR	1.5	TR
Dactylopterus volitans	1	0.5	1	TR	1.5	TR
Family Balistidae	22	11.2	43	0.7	126.8	0.9
Unidentifiable	2	1.0	2	TR	8.5	0.1
Unidentifiable triggerfish	1	0.5	1	TR	0.3	TR
Unidentifiable filefish	9	4.6	24	0.4	63.0	0.5
Aluterus sp.	1	0.5	1	TR	1.0	TR
Monacanthus sp.	3	1.5	9	0.1	28.0	0.2
M. hispidus	5	2.5	6	0.1	26.0	0.2
Family Ostraciidae	2	1.0	2	TR	0.8	TR
Unidentifiable boxfish	2	1.0	2	TR	0.8	TR
Family Tetraodontidae	3	1.5	3	0.1	0.9	TR
Unidentifiable puffer	2	1.0	2	TR	0.5	TR
Sphoeroides sp.	1	0.5	1	TR	0.4	TR
Family Diodontidae	10	5.1	40	0.7	104.2	0.8
Diodon sp.	9	4.6	39	0.7	101.2	0.8
Chilomycterus sp.	1	0.5	1	TR	3.0	TR
Invertebrates	167	85.2	5,114	87.5	6,543.4	49.1
Phylum Cnidaria	2	1.0	2	TR	1.5	TR
Class Scyphozoa	2	1.0	2	TR	1.5	TR
Phylum Mollusca	122	62.2	412	7.0	5,743.8	43.1
Unidentifiable	1	0.5	1	TR	0.2	TR
Class Cephalopoda	122	62.2	411	7.0	5,743.6	43.1
Unidentifiable	10	5.1	21	0.4	147.8	1.1

Table 1. (continued)

Item	F	%F	N	%N	V	%V
Order Teuthidida	99	50.5	364	6.2	5,457.4	41.0
Order Octopodida	15	7.7	26	0.4	138.4	1.0
Argonauta argo	15	7.7	26	0.4	138.4	1.1
Phylum Arthropoda	102	52.0	4,663	79.8	785.6	5.9
Class Crustacea	102	52.0	4,663	79.8	785.6	5.9
Unidentifiable	4	2.2	4	0.1	2.5	TR
Order Stomatopoda	15	7.7	90	1.5	15.7	0.1
Unidentifiable	1	0.5	1	TR	0.8	TR
Stomatopod larvae	13	6.6	88	1.5	14.9	0.1
Squilla empusa larvae	1	0.5	1	TR	TR	TR
Order Isopoda	5	2.5	64	1.1	46.7	0.4
Order Amphipoda	1	0.5	1	TR	0.2	TR
Suborder Gammaridea	1	0.5	1	TR	0.2	TR
Order Decapoda	92	46.9	4,504	77.1	720.5	5.4
Unidentifiable	3	1.5	3	0.1	1.0	TR
Unidentifiable larvae	1	0.5	4	0.1	0.5	TR
Suborder Natantia	28	14.3	102	1.7	39.5	0.3
Unidentifiable shrimp	4	2.0	6	0.1	8.6	0.1
Family Penaeidae	24	12.2	96	1.7	30.9	0.2
Cerataspis monstrosa larvae	20	10.2	85	1.5	28.5	0.2
C. petiti larvae	5	2.6	5	0.1	1.3	TR
Cerataspis sp. larvae	3	1.5	5	0.1	0.6	TR
Sicyonia brevirostris	1	0.5	1	TR	0.5	TR
Suborder Reptantia	81	41.3	4,395	75.2	679.5	5.1
Unidentifiable crab	1	0.5	1	TR	TR	TR
Unidentifiable megalopa	5	2.6	20	0.3	0.8	TR

Superfamily Scyllaridea (larvae)	1	0.5	1	TR	0.3	TR
Subfamily Diogeninae	4	2.0	6	0.1	0.4	TR
Diogenid glaucothoe	3	1.5	5	0.1	0.4	TR
Dardanus sp. glaucothoe	1	0.5	1	TR	TR	TR
Family Raninidae megalopa	54	27.5	4,258	72.9	541.2	4.1
Family Dromiidae megalopa	12	6.1	57	1.0	6.1	TR
Family Portunidae	14	7.1	53	0.9	98.2	0.7
Unidentifiable	3	1.5	7	0.1	2.1	TR
Portunus sayi	4	2.0	8	0.1	15.3	0.1
P. spinicarpus	5	2.5	34	0.6	73.9	0.5
Portunus sp.	3	1.5	4	0.1	6.9	0.1
Subphylum Urochordata	2	1.0	37	0.6	12.5	0.1
Class Ascidiacea	1	0.5	2	TR	0.5	TR
Class Thaliacea	1	0.5	35	0.6	12.0	0.1
Order Salpida	1	0.5	35	0.6	12.0	0.1
Miscellaneous	62	31.6	-	-	227.2	1.7
Sargassum sp.	52	26.5	-	-	186.3	1.4
Zostrea marina	5	2.6	-	-	4.9	TR
Thalassia testudinum	2	1.0	-	-	1.3	TR
Spartina sp.	3	1.5	-	-	11.0	TR
Unidentifiable food	5	2.5	-	-	8.2	0.1
Feather	3	1.5	-	-	1.8	TR
Tar ball	2	1.0	-	-	0.4	TR
White plastic	2	1.0	-	-	1.2	TR
Black/green plastic	1	0.5	-	-	0.2	TR
Blue plastic	1	0.5	-	-	0.1	TR
Clear plastic	1	0.5	-	-	0.2	TR
Clear plastic bag	1	0.5	-	-	12.0	0.1
				100.0		100.0

Table 2. Stomach contents of 89 blackfin tuna collected off the southeastern United States and Gulf of Mexico coasts in 1980 and 1981. F = frequency of occurrence (N=89); %F = percent frequency; N = number of items (N=1,120); %N = percent by number; V = volume (N=2,541.7 ml); %V = percent of volume.

Item	F	%F	N	%N	V	%V
Fish	60	67.4	286	25.5	1,720.8	67.7
Unidentifiable	40	44.9	92	8.2	482.8	19.0
Unidentifiable juvenile	7	7.9	37	3.3	13.6	0.5
Family Clupeidae	3	3.4	66	5.9	315.0	12.4
Unidentifiable	2	2.2	6	0.5	175.0	6.9
Etrumeus teres	1	1.1	60	5.4	140.0	5.5
Family Synodontidae	2	2.2	2	0.2	162.0	6.4
Synodus sp.	2	2.2	2	0.2	162.0	6.4
Family Batrachoididae	1	1.1	1	0.1	15.0	0.6
Porichthys porossimus	1	1.1	1	0.1	15.0	0.6
Family Syngnathidae	4	4.5	19	1.7	13.9	0.5
Hippocampus sp.	3	3.4	18	1.6	12.7	0.5
Unidentifiable pipefish	1	1.1	1	0.1	1.2	TR
Family Serranidae	1	1.1	1	0.1	33.0	1.3
Centropristis sp.	1	1.1	1	0.1	33.0	1.3
Family Carangidae	4	4.4	23	2.1	14.5	0.6
Caranx crysos	2	2.2	10	0.9	6.0	0.2
Seriola zonata	1	1.1	12	1.1	8.0	0.3
Vomer setapinnis	1	1.1	1	0.1	0.5	TR
Family Sparidae	3	3.4	4	0.4	92.0	3.6
Stenotomus caprinus	3	3.4	4	0.4	92.0	3.6
Family Sciaenidae	2	2.2	8	0.7	125.0	4.9
Cynoscion sp.	2	2.2	8	0.7	125.0	4.9
Family Mugilidae	1	1.1	1	0.1	27.0	1.1
Mugil sp.	1	1.1	1	0.1	27.0	1.1

Family Trichiuridae	5	5.6	7	0.6	164.0	6.4
Trichiurus lepturus	5	5.6	7	0.6	164.0	6.4
Family Stromateidae	2	2.2	7	0.6	110.0	4.3
Peprilus burti	1	1.1	5	0.4	60.0	2.4
P. triacanthus	1	1.1	2	0.2	50.0	2.0
Family Triglidae	1	1.1	1	0.1	20.0	0.8
Prionotus sp.	1	1.1	1	0.1	20.0	0.8
Family Balistidae	9	10.1	17	1.5	133.0	5.2
Unidentifiable	2	2.2	2	0.2	11.0	0.4
Unidentifiable triggerfish	3	3.4	6	0.5	62.0	2.4
Unidentifiable filefish	3	3.4	8	0.7	44.0	1.7
Monacanthus sp.	1	1.1	1	0.1	16.0	0.6
Invertebrates	73	82.0	834	74.5	787.9	31.0
Class Cephalopoda	32	36.0	72	6.4	575.1	22.6
Unidentifiable	1	1.1	1	0.1	0.2	TR
Order Teuthidida	28	31.5	68	6.1	545.4	21.5
Order Octopodida	3	3.4	3	0.3	29.5	1.2
Argonauta argo	3	3.4	3	0.3	29.5	1.2
Class Crustacea	60	67.4	762	68.0	212.8	8.4
Unidentifiable	3	3.4	3	0.3	5.8	0.2
Order Stomatopoda	31	34.8	356	31.8	105.9	4.2
Stomatopod larvae	30	33.7	347	31.0	59.4	2.3
Stomatopod postlarvae	1	1.1	2	0.2	0.5	TR
Squilla empusa adult	2	2.2	7	0.6	46.0	1.8
Suborder Hyperiidea (amphipod)	1	1.1	1	0.1	TR	TR
Order Decapoda	49	55.1	402	35.9	101.1	4.0
Unidentifiable larvae	1	1.1	2	0.2	TR	TR
Suborder Natantia	13	14.6	27	2.4	41.5	1.6
Unidentifiable shrimp	2	2.2	2	0.2	2.0	0.1
Section Penaeidea	13	14.6	23	2.0	39.3	1.5
Unidentifiable	1	1.1	3	0.3	7.0	0.3

Table 2. (continued)

Item	F	%F	N	%N	V	%V
Cerataspis monstrosa larvae	2	2.2	5	0.4	1.4	0.1
C. petiti larvae	2	2.2	2	0.2	0.3	TR
Penaeopsis goodei	1	1.1	1	0.1	1.0	TR
Sicyonia brevirostris	5	5.6	10	0.9	15.1	0.6
Sicyonia sp.	2	2.2	2	0.2	14.5	0.6
Section Caridea	2	2.2	2	0.2	0.2	TR
Suborder Reptantia	40	44.9	373	33.3	59.6	2.3
Unidentifiable megalopa	14	15.7	96	8.6	8.0	0.3
Subfamily Diogeninae glaucothoe	15	16.9	42	3.8	2.8	0.1
Section Brachyura	25	28.1	235	21.0	48.8	1.9
Unidentifiable zoea	1	1.1	3	0.3	0.1	TR
Family Raninidae megalopa	14	15.7	151	13.5	11.2	0.4
Family Dromiidae megalopa	11	12.4	71	6.3	11.8	0.5
Family Portunidae	4	4.5	10	0.9	25.7	1.0
Unidentifiable	1	1.1	3	0.3	18.0	0.7
Portunus sayi	2	2.2	6	0.5	7.5	0.3
Portunus sp.	1	1.1	1	0.1	0.2	TR
Miscellaneous	14	15.7	-	-	33.0	1.3
Sargassum sp.	11	12.4	-	-	26.6	1.0
Zostrea marina	2	2.2	-	-	0.5	TR
Unidentifiable food	3	3.4	-	-	4.9	0.2
White plastic	2	2.2	-	-	1.0	TR
				100.0		100.0

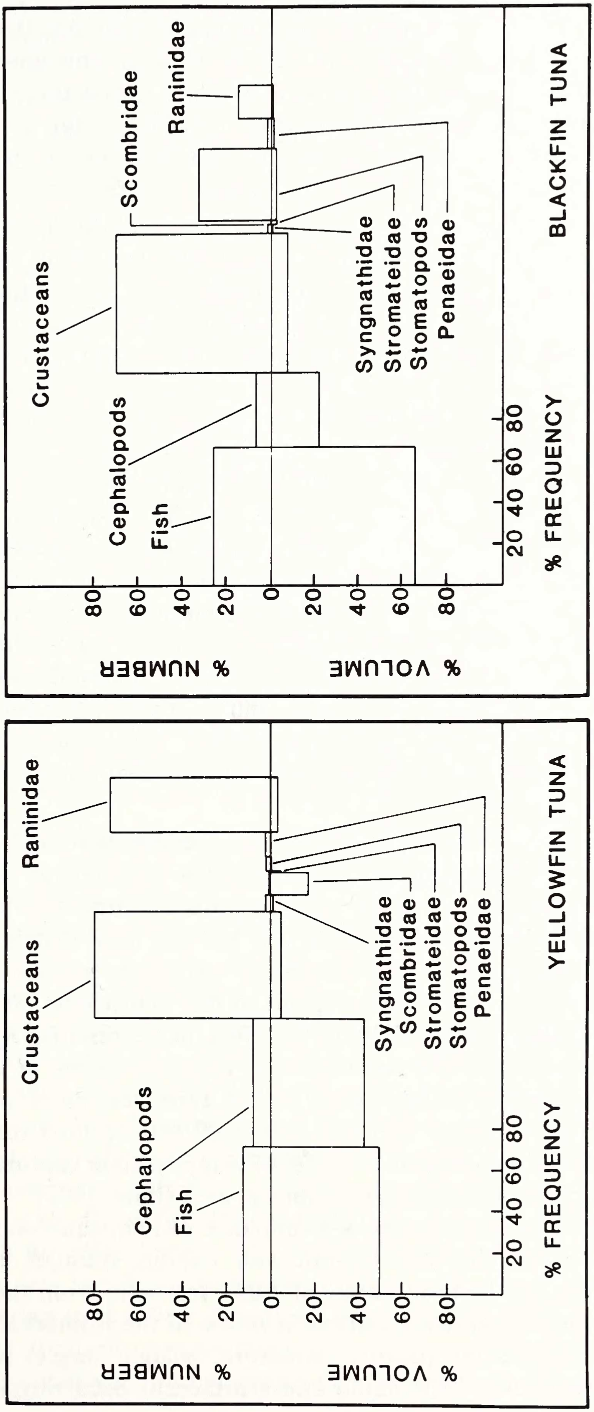

Fig. 2. Index of Relative Importance (IRI) plots for selected food items of yellowfin and blackfin tuna.

blackfin tuna. Percent volumes of these mollusks were less than 2% for both predators, and whereas over 430 squid were consumed by the tunas, less than 30 paper nautilus were eaten. At least three genera of squids were ingested: *Loligo*, *Sepioteuthis*, and *Illex*. Generic identifications were obtained by comparing saved, pooled samples with reference collection specimens and therefore do not appear in the tables.

Crustaceans.— Crustaceans, important foods of both species and second only to fish in overall frequency of occurrence, were identified in 52% of the yellowfin and in 67.4% of the blackfin. The majority were immature stages (larvae, megalopa and glaucothoe). Due to the small sizes of the animals, the relative percentages of the total food volume — 5.9% for yellowfin and 8.4% for blackfin — were comparatively small. Major taxa in the diet of yellowfin by frequency of occurrence were Raninidae (27.5%), Penaeidae (12.2%), Stomatopoda (7.7%), Portunidae (7.1%), and Dromiidae (6.1%). For blackfin tuna, the most frequently encountered were Stomatopoda (34.8%), Diogeninae (16.9%), Raninidae (15.7%), Penaeidae (14.6%), and Dromiidae (12.4%). In all, over 5,000 individuals were enumerated, and on one occasion a single predator contained hundreds of these small, mesopelagic invertebrates.

Our findings of the overall food habits seem to agree closely with those of Dragovich (1970), who described fish, cephalopods and crustaceans as the major foods of yellowfin and skipjack, *Katsuwonus pelamis*, tunas in the Atlantic. He also mentioned that larval and juvenile stages were prevalent for ingested fishes and macrozooplanktonic crustaceans.

Miscellaneous.— The very nature of tuna feeding, near-surface straining as well as actively pursuing and capturing larger animals, results in a variety of items being consumed that are probably ingested by accident along with natural foods. Yellowfin tuna had the most diverse assemblage of non-food items (31.6% frequency): plants (*Sargassum*, *Zostera*, *Thalassia* and *Spartina*), feathers, globs of tar, and plastic. Miscellaneous items occurred in only 15.7% of the blackfin, represented by *Sargassum*, *Zostera* and plastic. *Sargassum* was found in 26.5% of the stomachs with food, and usually occurred in tunas captured off North Carolina. This percentage is similar to the 37.8% reported for *Sargassum* removed from the digestive tracts of skipjack tuna captured earlier from approximately the same geographical area (Batts 1972).

Other studies also revealed a dominance of fish, squid and crustaceans in tuna diets for the Atlantic and Pacific. Reintjes and King (1953) investigated the food habits of 1,097 yellowfin from the Central Pacific and found that fish occurred in 70.4% of the stomachs; squid in 55.4%; and crustaceans (mostly immature, pelagic stages) in 66.9%. Alverson (1963) found fish, squid and crustaceans occurring in 53.8%, 23.9% and 76.1%, respectively, of the yellowfin he examined from the Pacific. Similar occurrences were reported for yellowfin from the Atlantic (Dragovich 1970), and for skipjack tuna (Alverson 1963; Nakamura 1965; Batts 1972); bluefin tuna, *T. thynnus* (Pinkus et al., 1971); and albacore, *T. alalunga* (Pinkas et al., 1971) from the Pacific.

COMPARATIVE DIETS

Since temporal and spatial variations in the diets were so great (data collected over a period of three years, and from several widely different geographical locations), we believed that only by analyzing small, discrete samples could we detect important differences in them. To achieve this, we used only stomach contents of the two species collected together off Oregon Inlet on 10 different days from May through September 1981 (Table 3).

Index of Relative Importance.— Indexes of Relative Importance (IRI), which present the combined contributions of volume, frequency of occurrence, and numbers of each food item to the diet (Table 3), showed that, surprisingly, invertebrates were very important foods for both species. The first five categories (ranks) for yellowfin were Teuthidida (squids), unidentifiable fish, Raninidae, Scombridae, and unidentifiable crustaceans. For blackfin they were unidentifiable fish, Teuthidida, Raninidae, Stomatopoda, and unidentifiable crustaceans. Obvious differences were more clupeids and unidentifiable diogenid crabs in blackfin, and more scombrids and squids in yellowfin. Other items were also different, but their respective IRI values were relatively small (i.e., exocoetids for yellowfin = 9.7, for blackfin = 0.0).

Correlation Coefficients.— Data from Table 3, ranked by IRI values, were used to obtain quantitative comparisons of local food habits of the two species. Three different measures were used: Spearman Rank Correlation Coefficient (Fritz 1974); Kendall Rank Correlation Coefficient (Bray and Ebeling 1975); and Pearson Product-moment Correlation Coefficient (Goodall 1973). The first two require no assumption of normality with regard to the distribution of the two predator species, whereas the latter does. Cailliet and Barry (1978), who compared the three methods of analyzing diets that have different distributions of prey items, found that Spearman and Kendall correlation coefficients are somewhat unpredictable when there are 1) a large number of ties, 2) a considerable nonoverlap of prey items, and 3) high prey richness and evenness (i.e., diversity). They felt that the Pearson method was best. Although our data have a fairly low richness and evenness, there are relatively few ties (2 for yellowfin, 3 for blackfin) and there is a fairly good overlap in the diets. For these reasons all three methods of measuring diet similarity are probably appropriate. Qualitatively, both species feed extensively on epipelagic and mesopelagic fishes and inverte-

Table 3. Frequency of occurrence, numeric and volumetric percentages, IRI values, and rankings of stomach contents from 45 yellowfin and 35 blackfin captured simultaneously off Oregon Inlet in 1981. %F = percent frequency; %N = percent by number; %V = percent by volume.

Item	Yellowfin tuna %F (N=45)	%N (N=439)	%V (N=2,427.2 ml)	IRI	Rank	Blackfin tuna %F (N=35)	%N (N=416)	%V (N=653.1 ml)	IRI	Rank
Unidentifiable fish	55.5	10.9	9.3	1,121.1	28.0	54.3	11.1	18.0	1,580.1	29.0
Clupeidae				0.0	4.5	5.7	15.1	30.6	260.5	24.0
Exocoetidae	4.4	0.5	1.7	9.7	19.0				0.0	5.5
Syngnathidae	6.7	7.3	1.4	58.3	23.0	5.7	4.1	1.9	34.2	21.0
Priacanthidae	2.2	0.2	0.0	0.4	9.5				0.0	5.5
Carangidae	4.4	0.7	1.9	11.4	20.0	5.7	5.0	2.0	39.9	22.0
Scombridae	13.3	1.6	13.9	206.2	26.0				0.0	5.5
Stromateidae				0.0	4.5	2.9	0.5	7.7	23.8	20.0
Balistidae	6.7	0.7	0.7	9.4	18.0				0.0	5.5
Diodontidae	2.2	0.5	3.5	8.8	17.0				0.0	5.5
Teuthidida	68.9	22.3	61.4	5,766.9	29.0	37.1	5.3	35.2	1,502.6	28.0
Octopodida	4.4	0.5	0.8	5.7	15.0	2.9	0.2	0.5	2.0	15.5
Unidentifiable crustaceans	8.9	13.9	1.9	140.6	25.0	28.6	9.9	1.2	317.5	25.0
Stomatopoda	13.3	9.1	0.3	125.0	24.0	42.9	14.9	1.2	690.7	26.0
Amphipoda				0.0	4.5	2.9	0.2	0.0	0.6	12.5
Unidentifiable Natantia	2.2	0.4	0.1	1.1	11.0	2.9	0.2	0.0	0.6	12.5
Cerataspis monstrosa	2.2	1.1	0.1	2.6	13.0				0.0	5.5
C. petiti				0.0	4.5	2.9	0.2	0.0	0.6	12.5
Sicyonia brevirostris				0.0	4.5	5.7	0.7	0.1	4.6	18.0
Caridea				0.0	4.5	2.9	0.2	0.0	0.6	12.5
Unidentifiable Reptantia				0.0	4.5	2.9	0.7	0.0	2.0	15.5
Scyllaridea	2.2	0.2	0.0	0.4	9.5				0.0	5.5
Diogeninae	2.2	0.7	0.0	1.5	12.0	22.9	6.3	0.2	148.9	23.0
Raninidae	17.8	13.9	0.3	252.8	27.0	28.6	23.1	1.2	695.0	27.0
Dromiidae	4.4	0.9	0.0	4.0	14.0	8.6	1.4	0.1	12.9	19.0
Unidentifiable Portunidae	2.2	3.4	0.4	8.4	16.0				0.0	5.5
Portunus spinicarpus	4.4	3.2	1.9	22.4	22.0				0.0	5.5
P. sayi				0.0	4.5	2.9	0.7	0.1	2.3	17.0
Salpida	2.2	8.0	0.5	18.7	21.0				0.0	5.5

brates. Eleven of the 28 food categories occurred in the stomachs of both species, and 6 of the 10 most important categories to blackfin also ranked in the top 10 for yellowfin. The obvious conclusion is that both species have similar diets when they occur together off the coast of North Carolina. Statistically, however, the correlation coefficients were all nonsignificant at the 0.05 (0.344; 29 df) level. The correlation coefficients were: Spearman, 0.2273; Kendall, 0.1451; and Pearson, 0.2273.

Comparative Diets by Predator Size

Differences in stomach contents by fish size may of course be attributable merely to the availability of food in the environment, but they may also be attributable either to a change in food preference, or to the ability of the predator to capture and swallow certain organisms as it increases in size. Our objectives of comparing diets by tuna size were to determine if near-surface feeding was related to tuna size and to ascertain if basic changes in the diets occurred as the fish grew larger.

Different studies throughout the world's oceans generally suggest that as tunas grow larger, their diets change. Reintjes and King (1953) reported that the overall high occurrence of crab larvae, stomatopod larvae, squid, and juvenile fishes indicates a preference by Pacific yellowfin tuna for small food items. These authors further explained that small tuna feed predominantly on crustacean larvae; medium-size fish feed on fish, crustacean larvae, and squid; and large yellowfin mainly consume fish and squid. These findings were substantiated by Nakamura (1965) and Batts (1972) for skipjack tuna whose diets reflected a decline in crustaceans and a subsequent higher percentage of fish, as tuna size increased.

To accomplish our evaluations we first grouped the fish into size classes (mm FL) (Tables 4, 5). Next, selected food groups — fish, adult fish, juvenile fish, invertebrates, squid, larval crustaceans and plants — were established to demonstrate food size (i.e., adult fish vs. larval crus-

Table 4. Selected food items consumed by different sized yellowfin tuna, expressed as percent frequencies of occurrence.

	Fish size (mm FL)			
Contents	501-700	701-900	901-1100	>1100
Fish	77.8	81.8	75.0	73.8
Adult fish	5.5	10.9	15.0	9.5
Juvenile fish	16.7	12.7	36.4	11.9
Invertebrates	77.8	89.1	76.3	85.7
Squid	44.4	34.5	56.3	64.3
Larval crustaceans	38.9	70.9	35.0	35.7
Plants	55.5	32.7	30.0	14.3

Table 5. Selected food items consumed by different sized blackfin tuna, expressed as percent frequency of occurrence.

Contents	Fish size (mm FL)			
	<500	501-700	701-900	901-1100
Fish	50.0	57.4	87.1	100.0
Adult fish	0.0	7.4	25.8	0.0
Juvenile fish	50.0	16.7	9.7	0.0
Invertebrates	100.0	90.7	64.5	100.0
Squid	50.0	31.5	25.8	100.0
Larval crustaceans	100.0	66.7	38.7	0.0
Plants	50.0	14.8	9.7	0.0

taceans) and materials that we believed to be consumed on or near the surface (i.e., floating plants). Contents are presented as percent frequency of occurrence (Tables 4, 5).

Yellowfin Tuna.— Size of food items showed little change as fish size increased or decreased (Table 4). The three key food categories — adult fish, juvenile fish, and larval crustaceans — neither steadily increased nor decreased in occurrence as tuna size increased. This finding is contrary to that of Dragovich (1970), who found that the frequency occurrence of fish in stomachs of yellowfin increased with fish size. However, he discovered no relationship between squid in the diet and tuna size. In our study, the occurrence of floating plants decreased for the larger size classes, indicating that perhaps smaller individuals fed more extensively near the surface.

Blackfin Tuna.— The size of prey items and feeding proximity to the surface appeared to change with fish size. As fish size increased, large food items (i.e., adult fish) generally occurred more frequently, and small food items (i.e., larvel crustaceans and juvenile fish) occurred less frequently (Table 5). Surface feeding, as suggested by the incidental ingestion of floating plants, decreased as fish attained larger sizes.

Volumes of Contents Related to Species and Fish Body Weight

Since the quantity and types of foods ingested by fishes are often converted into caloric equivalents for energetics studies, we present frequencies of the range of food volumes for the two species (Table 6). The displacement volume for yellowfin averaged 67.9 ml (72.2 g), compared with 28.6 ml (29.6 g) for blackfin tuna. Volumes of stomach contents of yellowfin and blackfin varied from 0.1 to 745.0 ml and from 0.1 to 257.5 ml, respectively. The largest volumes were found in a 40 kg yellowfin and an 8.8 kg blackfin. The volume range for yellowfin from the Pacific was similar, 0.1 to 1,000 ml (Reintjes and King, 1953). The extremes in our data were much greater than those described by Dragovich and Potthoff (1972): 0.1 to 20.0 for skipjack, and 0.1 to 60.0 ml for yellowfin tunas collected off the west coast of Africa. In our study, approxi-

Table 6. Frequencies of food volumes by species of tuna.

Volume range (ml)	Yellowfin tuna Number	Yellowfin tuna Percent	Blackfin tuna Number	Blackfin tuna Percent
0.1- 10.0	64	32.6	46	51.7
10.1- 50.0	67	34.2	26	29.2
50.1-100.0	24	12.2	10	11.2
100.1-150.0	15	7.7	3	3.4
150.1-200.0	9	4.6	3	3.4
200.1-250.0	6	3.1	-	
250.1-300.0	3	1.5	1	1.1
300.1-350.0	3	1.5	-	-
350.1-400.0	1	0.5	-	-
400.1-450.0	1	0.5	-	-
450.1-500.0	1	0.5		
500.1-550.0	-	-	-	-
550.1-600.0	-	-	-	-
600.1-650.0	-	-	-	-
650.1-700.0	1	0.5	-	-
700.1-750.0	1	0.5	-	-
Totals	196	99.9	89	100.0

mately 33% of the yellowfin had food volumes exceeding 50 ml, a proportion similar to that of the 29% found by Reintjes and King (1953). By comparison, Dragovich (1970) noted volumes of less than 20 ml for 85% of the yellowfin from the Atlantic. We found that only 19% of the blackfin, a much smaller species, had contents over 50 ml.

To determine the relationship of volume to fish body weight, we first derived the following equation for converting volume in ml to volume in grams:

$$Vol_g = -1.4009 + 1.0846\,(Vol_{ml}),\ N=25,\ r=0.999.$$

Comparisons were then made between estimates of stomach contents and the body weights of some of the tunas selected at random. Percentages of food weight to fish weight varied from trace (<0.002) to 2.02 for yellowfin, and from 0.02 to 3.20 for blackfin tuna. Only 10% of the yellowfin had contents exceeding 1% of fish body weight, whereas 20% of the blackfin tuna had contents exceeding this percentage. Usually our observations were well below 1%, as were those of Dragovich (1970).

In summary, yellowfin and blackfin tuna appear to be fast, aggressive predators capable of capturing swift, relatively large prey. On the other hand, they use their gill apparatus to strain small, near-surface items from the water. During feeding, non-food materials (inorganic as well as organic) are ingested, probably incidental to normal prey. The variability of specific food organisms within the major categories (fish, cephalopods, and crustaceans) in the diets suggests that tunas are non-selective feeders. This is undoubtedly a factor in their wide geographic distribution, and one would expect, therefore, for the diets of such well-traveled fish to be rather cosmopolitan.

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